Theory and practice of multiplicity measurements in nuclear safeguards

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The purpose of nuclear safeguards is to detect, identify and quantify fissile material. Measuring several neutrons and/or gamma photons in coincidence, emitted from an unknown sample is a non-destructive way of achieving this task. Many of the fissile/fissionable nuclei are neutron and gamma emitters through spontaneous fission. They can be distinguished from ordinary radioactive sources (Am-Be etc) in that unlike in the latter, the probability of simultaneous detection of two or more neutrons is larger than zero, and the statistics of the number of counts during a time period from a detector with sufficiently high efficiency deviates from that of pure Poisson distribution, i.e. the variance is larger than the mean. In addition, with increasing sample size, the probability that the source neutrons (from the spontaneous fission) induce further fissions and hence further neutrons, increases monotonically, which changes the detection statistics further, and this gives a possibility to determine the mass of the sample.

In the talk the theory of multiplicity and coincidence measurements will be explained by showing how probability balance equations can be formulated based on by basic principles of probability theory. From these equations the first few lowest order moments of the neutron multiplicity can be derived in closed analytical form, as functions of the material properties of the sample and its mass. It will be shown how with an inversion of the multiplicity formulas, these parameters can be unfolded by measuring the rate of detecting singles, doubles and triplets in coincidence.

[1] Pázsit I. and Pál L. Neutron fluctuations – a Treatise on the Physics of Branching Processes. Elsevier, 2008.